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# ANALYSIS OF AGROCLIMATIC RESOURCES IN ROMANIA IN THE CURRENT AND FORESEEABLE CLIMATE CHANGE - CONCEPT AND METHODOLOGY OF APPROACHING

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***Abstract***

*Analyzes of the effects of climate change in agriculture is a priority in the strategic development actions in EU member countries and beyond. The interdisciplinary character of actions involves a comprehensive approach by identifying and linking activities to develop and implement measures intra and inter-sectoral those related to climate change in agriculture and related fields. Climate variability affects all sectors but agriculture remains the most vulnerable. Crop production varies year by year, it is significantly influenced by fluctuations in weather conditions and in particular the production of extreme weather events. In Romania, climate change has and will have a significant impact on the development of natural conditions, agriculture and biodiversity are the areas most vulnerable to climate change, given the dependence on climatic conditions and the negative ecological, economic and social. From an economic perspective, this phenomenon causes a reduction to total compromise agricultural production, with serious implications on food security of the population.*

***Key words**: agriculture, agrometeorology, climate change, impact, vulnerability.*

## INTRODUCTION

The climate is changing globally and in Europe. The Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2013) concluded that the warming since the mid-20$^{th}$ century has predominantly been due to greenhouse gas emissions from human activities, in particular the combustion of fossil fuels, agriculture and other changes in land use.
The Paris Agreement adopted by 195 nations at the 21$^{st}$ Conference of the Parties to the UNFCCC in **December 2015** included the aim of strengthening the global response to the threat of climate change by “holding the increase in the global average temperature to well below 2°C above preindustrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels“.
There has been a steady increase over the last five years in national adaptation strategies and plans. By September 2016, 20 of EU Member States had adopted a national adaptation strategy and 12 (of which nine are Member States) had developed a **national adaptation plan**. Most progress regarding action plans has been reported for freshwater management, flood risk management, **agriculture** and forestry, with a focus on mainstreaming adaptation in these national sectoral policy areas.
On **8$^{th}$ October 2018**, at INCHEON, Republic of Korea, the IPCC approved *The Special Report (SR15)* where the new limiting global warming to 1.5°C would require rapid, far reaching and unprecedented changes in all aspects of society.
With clear benefits to people and natural ecosystems, limiting global warming to 1.5°C compared to 2°C could go hand in hand with ensuring a more sustainable and equitable society.
The report’s full name is *Global Warming of 1.5°C, an IPCC special report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty* (IPCC, October 2018).

**What is the IPCC?**

The Intergovernmental Panel on Climate Change (IPCC) is the UN body for assessing the science related to climate change. It was established by the United Nations Environment Programme (UN Environment) and the World Meteorological Organization (WMO) in 1988 to provide policymakers with regular scientific assessments concerning climate change, its implications and potential future risks, as well as to put forward adaptation and mitigation strategies. It has 195 member states.

IPCC assessments provide governments, at all levels, with scientific information that they can use to develop climate policies. IPCC assessments are a key input into the international negotiations to tackle climate change. IPCC reports are drafted and reviewed in several stages, thus guaranteeing objectivity and transparency

Study of meteorological parameters of risk with impact on the vegetation and productivity of agricultural crops through different criteria of characterization - definition, main characteristics, agrometeorological risk aspects, as well as identification - spatio-temporal variability, frequency, intensity, succession, production duration, years extremes, extreme events etc., allows to know the vulnerability of agricultural species to the production of meteorological or climatic risk/stress phenomena and to determine the ways of using the agroclimatic potential of the areas of agricultural interest.

The degree of vulnerability of agricultural species to their production as well as of the agricultural territory as a whole is established through different reference thresholds/levels and risk classes in order to assess the agroclimatic degree of agroclimatic favorability of agricultural areas for varieties and agricultural species of varying degrees resistance to their production.

## MATERIALS AND METHODS

In the current study, meteorological data and agrometeorological data from different periods/years (1981-2010, 2011-2018) were analyzed and interpreted.

The meteorological parameters (NMA database) used are the maximum and minimum daily temperatures, the average monthly air temperature, wind speed, sunshine duration, relative air humidity, monthly precipitation average, with the aim of highlighting a set of agrometeorological indicators used at European level in the field of agriculture.

The climatic parameters mentioned have been used to establish agrometeorological indicators, such as: scorching heat, precipitation during the agricultural year (September-August), soil moisture in the main agricultural crops.

The “scorching heat” phenomenon is characterized by the evolution in the dynamics of the maximum daily air temperatures exceeding the limiting biological parquets of the plants, expressed in the amount of the "heat units”, as well as in the intensity of the phenomenon during the active vegetation season (April-September) or characteristic intervals for the main field crops.

Precipitation is an agrometeorological reference indicator for an agricultural area, against which extreme years can be reported, considered agroclimatic risk. This value expresses the potential of rainfall resources useful in determining the degree of pluviometric favorability of an agricultural area for a species, namely variety or hybrid. In this way, a clear picture of the possibilities of expanding into the culture of those genotypes/varieties or hybrids, with economically efficient production on the surface unit, is obtained.

The soil moisture reserve (mc/ha) was analyzed on different profiles and calendar dates specific to field crops, correlated with the periods with maximum water requirements in summer.

In this analyze GIS techniques were used to graphically represent the dynamics of agro-meteorological parameters: scorching heat, rainfall and soil moisture.

## RESULTS AND DISCUSSIONS

**Almost all European countries** have conducted national climate change vulnerability and risk assessments (Figure 1). In this context, the Southern Europe is more vulnerable to climate change several sectors will be affected such as: agriculture, forestry, energy, infrastructure, human health etc. Climate projections (JRC, Russo et al., 2014) show a marked increase in high temperature extremes, meteorological droughts, and heavy precipitation events with variations across Europe.

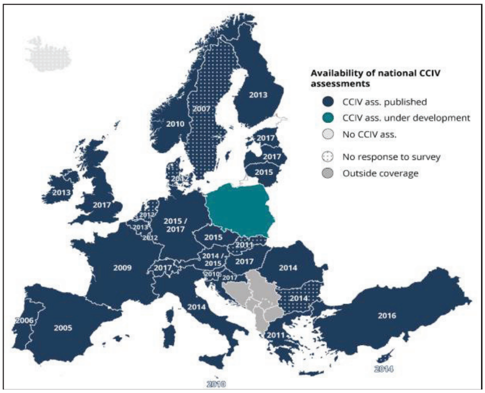


Figure 1. National climate change vulnerability and risk assessments in Europe (Source: EEA, 2018)

These scenarios show us that into the period 2020-2052, the number of projected extreme heatwaves will be highest in southern Europe with 3-6 extreme heatwaves over 33 years (i.e. one every 5-10 years) and for the future interval 2068-2100, will we have 12-15 extreme heat waves over 33 years (i.e. one every 2-3 years) in some parts of Southern Europe (Figure 2).

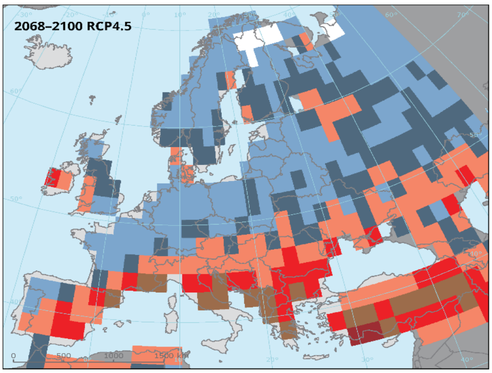


Figure 2. Heat Wave Magnitude Index (HWMI) is based on the magnitude and length of heat waves in a year, where heat waves are periods of at least 3 consecutive days with maximum temperature above the threshold for the reference period 1981-2010 (Source: JRC, Russo et al., 2014)

In this context, Romania is already facing the current environmental stresses, including increasing vulnerability in the intensity and frequency of climatic extremes (drought, floods, heat, frost, diseases and pests etc.), which cause significant losses in all economic sectors , but especially in agriculture, which is the most time-dependent sector. Every physical, chemical and biological process that determines the growth and development of agricultural crops is regulated by specific climatic requirements and any deviation from these requirements can result in great variability in the level of agricultural output, and implicitly, major negative consequences on food security. Agricultural production will be affected by predictable variability and climate change, especially in high-risk farming areas with low potential for adaptation.

In Romania, the changes in the climate regime are in the global context, but with the particularities of the geographical region in which our country is located. Thus, at the level of the period 1901-2018, the analysis of the average annual air temperature values from a number of 29 meteorological stations with a consecutive series of observations over 100 years (Figure 3) shows that the average annual temperature increased by 0.7°C in the period 2000-2018 (11.7°C) over the whole analyzed period (9.3°C).

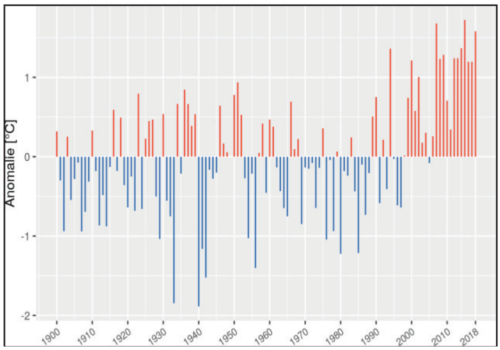


Figure 3. Deviations of the annual average temperature in Romania, 1901-2018 (NMA, 2018)

In the last 30 years, the warmest year was 2015 (11.7°C) and the coldest 1985 (8.4°C) (Table 1). Also, in Romania, the effects climate change has had and will have a significant impact on the evolution of natural conditions, agriculture and biodiversity are the areas most vulnerable to climate change, given dependend climatic conditions and the negative ecological, economic and social.

Table 1. The warmest years in Romania

| No | Year | Mean annual air temperature (°C) | Deviation |
|---|---|---|---|
| **1** | 2015 | 11.72 | 1.7371 |
| **2** | 2007 | 11.67 | 1.6916 |
| **3** | **2018** | **11.57** | **1.5805** |
| **4** | 2014 | 11.36 | 1.3808 |
| **5** | 1994 | 11.35 | 1.3748 |
| **6** | 2009 | 11.28 | 1.2972 |
| **7** | 2013 | 11.23 | 1.2546 |
| **8** | 2012 | 11.23 | 1.2538 |
| **9** | 2008 | 11.23 | 1.2466 |
| **10** | 2000 | 11.21 | 1.2270 |
| **11** | 2016 | 11.19 | 1.2095 |
| **12** | 2017 | 11.19 | 1.2094 |
| **13** | 2002 | 11.00 | 1.0175 |

These extreme weather events cause a significant economic loss in agriculture, transport, energy supply, water management, etc., and global climate models indicated that the frequency and intensity of these events can only be expected to increase.

Thus, may cause drought and reduce the potential for degradation of biological farmland soil. From an economic perspective, this phenomenon causes the decrease to total compromise agricultural production, with significant implications on food security of the population. In social, drought condition generates poverty, especially among the rural population, mainly dependent on agricultural activities.

Drought is a major natural hazard having different definitions depending on the type of impact or socio-economic activity which is affected. From the meteorological point of view, a drought period is defined by a significant deficit in the precipitation regime. Pedological drought refers to a significant deficit in the soil moisture. For agriculture, drought is defined by parameters affecting crops growth and production.

In Romania, approximately 14.7 million ha of agricultural land (of which 9.4 million hectares of arable land), soils are affected by drought for long periods and in consecutive years on an area of approx. 7 million hectares of arable land (48%) or excess moisture in the rainy years (about 4 million hectares). Drought is the limiting factor affecting crop production on the largest surface extension and intensity of this type of risk reduction causing fluid annual agricultural production by at least 30-50%.

In Romania, drought-affected areas have expanded over the past decades. The most affected areas are in the South and South-East of Romania, but the entire country has felt the effects of extensive pedological drought, especially in the last 30 years.

Since 1961 until now, Romania has seen in every decade one to four extremely droughty/rainy years, an increasing number of droughts being more and more apparent after 1981 (Table 2).

Table 2. Droughty/rainy years in Romania (1961-2020)

| DECADE | XX-TH CENTURY | |
|---|---|---|
| | EXTREMELY DROUGHTY YEARS | EXTREMELY RAINY YEARS |
| 1961-1970 | 1962-1963, 1964-1965 | 1969, 1970 |
| 1971-1980 | 1973-1974, 1975-1976 | 1972, 1974, 1975, 1976 |
| 1981-1990 | 1982-1983, 1985-1986, 1987-1988, 1989-1990 | 1981, 1990 |
| 1991-2000 | 1992-1993, 1999-2000 | 1991, 1997 |
| | XXI-TH CENTURY | |
| 2001-2010 | 2000-2001, 2001-2002, 2002-2003, 2006-2007, 2008-2009 | 2005, 2006, 2008, 2010 |
| 2011-2020 | 2011-2012, 2014-2015, 2015-2016, 2016-2017 | 2013 |

In the 21-th Century, 2006-2007, 2011-2012 and 2014-2015 were included in the list of the most droughty years, both through the intensity of the in-soil water deficits and through the duration of the scanty intervals and wideness of the surfaces affected by pedological drought (extreme, severe and moderate) in almost all areas of the country.

The analysis of the average monthly air temperature values in the 2006-2007 agricultural year shows that in 11 of the 12 months (February, March, April, May, June, August, September, October, November, December), average temperatures - above the climatological norms, the maximum deviation from the reference period was recorded in September, ie +3.8°C (Figure 4).

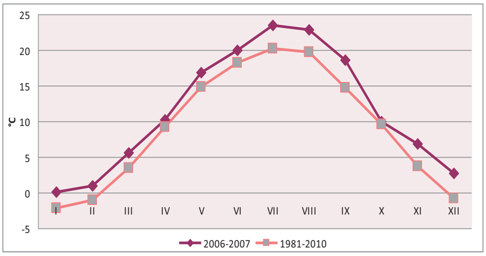


Figure 4. Monthly average air temperature variation in the agricultural year 2006-2007 as compared to multiannual averages (1981-2010)

In the agricultural year 2011-2012, the average monthly air temperature shows that only 3 of the 12 months, January, February and December respectively, show negative deviations from the reference period, the negative deviation being -5.4°C (Figure 5).

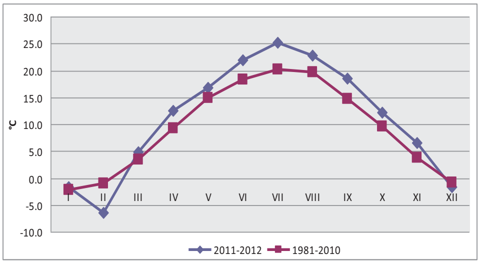


Figure 5. Monthly average air temperature variation in the agricultural year 2011-2012 as compared to multiannual averages (1981-2010)

The analysis of the average monthly air temperature values in the 2014-2015 agricultural year shows that during the longest part of the period the average temperatures were above the climatological norms, the maximum deviation from the reference period being recorded in July, respectively +3.8°C (Figure 6).

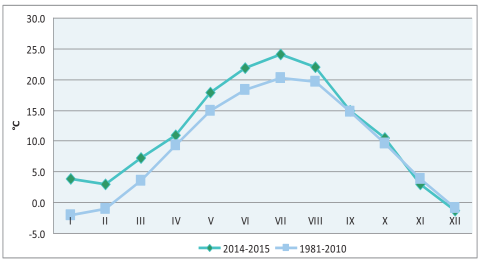


Figure 6. Monthly average air temperature variation in the agricultural year 2014-2015 as compared to multiannual averages (1981-2010)

In Romania, the NMA is covering the Agro-meteorology domain and processes the meteorological information as well as analyzes how weather conditions influence the processes of growing and developing crops/vines. The Department of Agrometeorology studying the agrometeorological parameters (humidity reserve, potential ETP-evapotranspiration, minimum, average and maximum air temperature, soil temperature, sunshine duration, wind speed, relative humidity, winter severity-, heat-units of heat/number of days, imprinting index) and establishes how to highlight and develop cultures through the development phases of both crops and fruit and wine species.

The ***scorching heat*** phenomenon is one of the most important agrometeorological risk factors that can have negative effects on plant growth and development processes. The evolution of scorching heat intensity in Romania from 1961 to 2018 shows an increasing trend especially after 1981 (Figure 7).

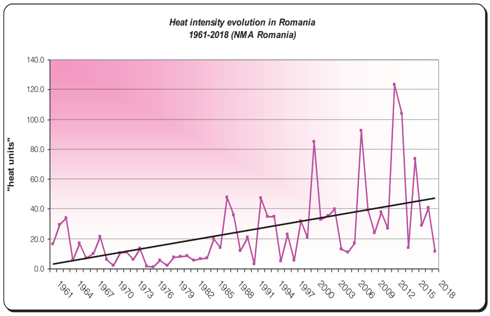


Figure 7. The evolution of scorching heat intensity in Romania, 1961-2018 (NMA Agrometeorology)

Given the multi-annual means of scorching heat intensity, phenomenon quantified by sums of air temperature highs equal to or above 32°C recorded during the summer months, it has become apparent a significantly higher thermal stress over the critical interval for crops (June-August), an increase from 13 units of scorching heat between 1961 and 1990 to 28 units over 1981-2010 (Figure 8).

In 2007, 2012 and 2015 the highest values of the heat scorching of the year were recorded on the agrometeorological stations: Giurgiu (2007-222.5 units, 2012-296.2 units) and Calafat (2015-182.0 units) (Table 3).

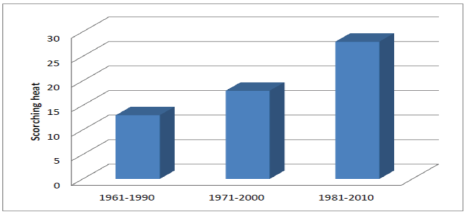


Figure 8. Intensity of scorching heat intensity in Romania, by 30 years interval, 1961-2010

Table 3. Maximum heat units in the most droughty years of the XXI Century in Romania

| Year | Station | Heat units |
|---|---|---|
| 2001 | Băilești | 127.0 |
| 2002 | Băilești | 102.9 |
| 2003 | Calafat | 141.8 |
| 2004 | Calafat | 70.1 |
| 2005 | Calafat | 38.0 |
| 2006 | Turnu Măgurele | 65.2 |
| **2007** | **Giurgiu** | **222.5** |
| 2008 | Bechet | 127.4 |
| 2009 | Giurgiu | 84.2 |
| 2010 | Calafat | 107.6 |
| 2011 | Calafat | 105.9 |
| **2012** | **Giurgiu** | **296.2** |
| 2013 | Calafat | 142.0 |
| 2014 | Turnu Măgurele | 53.9 |
| **2015** | **Calafat** | **182.4** |

***Precipitation*** is the main source of water for the growth and development of agricultural crops, and the most significant elements of this meteorological parameter are the quantitative variability, the distribution and the spatio-temporal distribution.

Knowing the periods of deficiency/surplus in rainfall for each zone/agricultural region allows the choice of the crops/varieties that are most suitable for the area of interest, as well as the establishment of the pedoameliorative, agrofitotechnical and economic-organizational protection measures necessary for the production process in the agricultural field.

The precipitation regime, the 2011-2012 agricultural year was excessively droughty at the scale of the whole country's agricultural territory, with precipitation deficits even more severe than in the landmark droughty year 2006-2007.

The Figure 9 exemplifies the precipitation amounts' territorial distribution in the 2006-2007, 2011-2012 and 2015-2015 agricultural years, comparatively with 1981-2010.

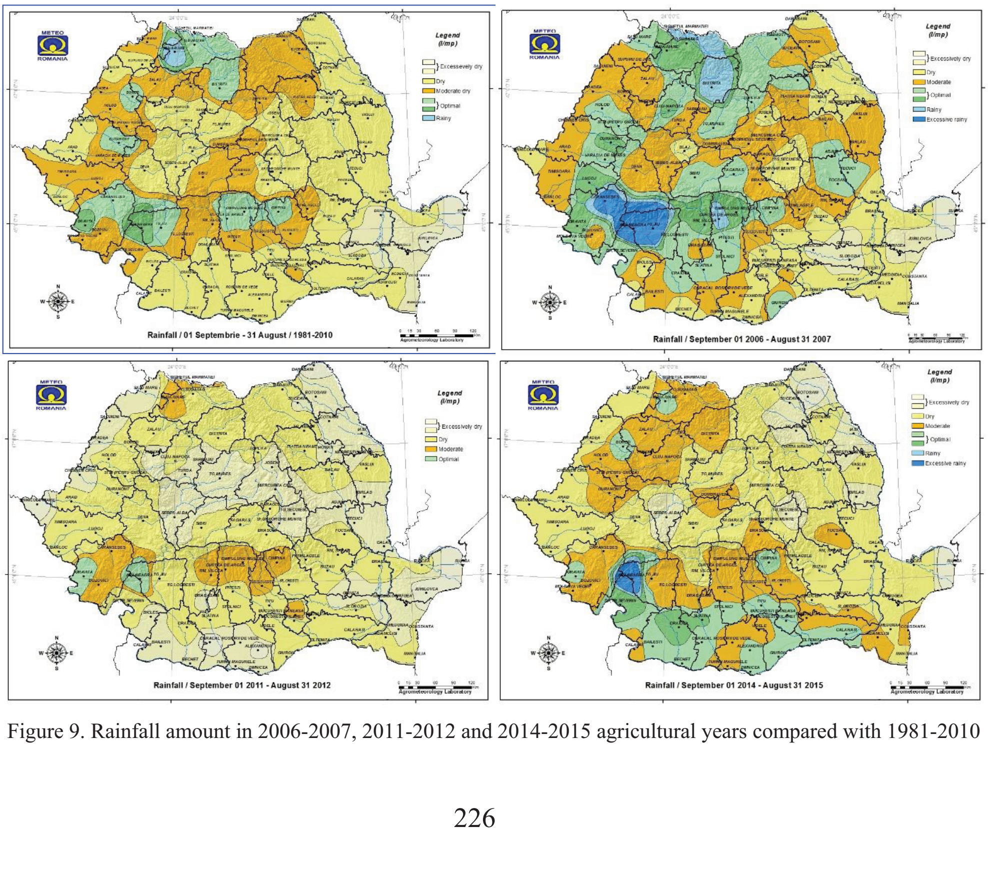


Figure 9. Rainfall amount in 2006-2007, 2011-2012 and 2014-2015 agricultural years compared with 1981-2010

Soil water reserve in soil layer 0-100 cm in non-irrigated corn crop on August 31, 2007, low values (moderate pedological drought) and particularly low (strong and extreme soil drought) on extended areas in the West, South, South-East and East of the country. Local to the West, center, Northeast and isolated in the East of the country, water supply to the soil ranged within satisfactory and close to optimal limits.

At the end of August 2012, in the non-irrigated corn crop, the water supply of the soil at the depth of the soil 0-100 cm present low and particularly low values, the pedological drought being moderate, strong and extreme on almost the entire agricultural territory of the country, with the exception of some areas in the Northwest of Moldova, where the supply of water to the soil was within satisfactory limits.

The moisture content in the 0-100 cm soil layer in non-irrigated maize culture on August 31, 2015 was low (moderate pedological drought) and particularly low (strong and extreme soil drought) for the most part cultural areas. On the agricultural areas in central and Western Transylvania, the center of Oltenia, isolated in the West, South and East of Muntenia, Southeastern Dobrogea and Northern Moldova, the water supply of the soil was within satisfactory and isolated limits close to the optimum (Figure 10).

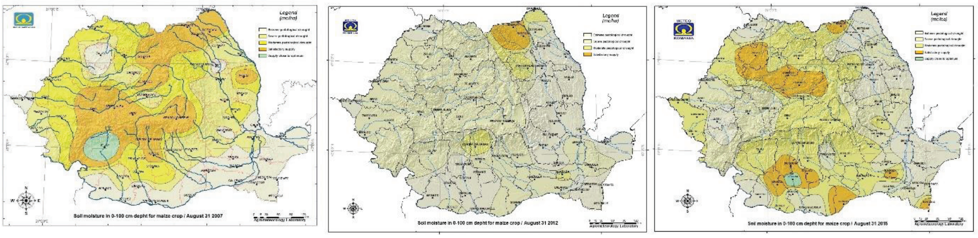

Figure 10. Moisture reserve in the soil layer 0-100 cm in corn crops on 31 August 2007, 2012 and 2015

Due to the maintenance of the water stress associated with the thermal in the air and the long-term soil, the non-irrigated pruning crops (corn and sunflower) maturation processes were hampered over all three analyzed years, with sub-dimensioning of the element elements small diameter head and dry sunflower seeds (Figure 11), as well as small sized oysters and shrimps on corn.

Figure 11. The state of vegetation (2007-2012) in Călărăşi/Muntenia and Adamclisi/Dobrogea in the sunflower and corn crops (NMA Agrometeorology Network)

Also, undersized and dehydrated fruits and their premature fall were reported in the tree species.

The effects of the phenomenon of pedological drought on the growth and development of agricultural plants are cumulative (Figure 12), depending on the intensity and duration, the consequences being accentuated when the action of thermal and water stress in the air and soil is combined (complex agricultural drought) and long lasting (>10-15 days consecutive, particularly in critical crop periods).

Figure 12. The state of vegetation-summer 2015 in Iasi/ Moldova in the sunflower and corn crops (NMA Agrometeorology Network)

The agricultural year 2006-2007 marked as the most droughty for the agriculture sector, with peak intensity especially in the south and south-east of the country, where the harvest was totally compromised. But, the 2011-2012 agricultural year can be considered excessively droughty, both through the intensity of the in-soil water deficits and through the duration of the scanty intervals and wideness of the surfaces affected by pedological drought (extreme, severe and moderate) in the almost all areas of the country.

The agroclimatic potential of a cropping area provides information on assessing the natural conditions of vegetation and the vulnerability of agricultural areas to the production of risk/stress phenomena that can cause significant annual deviations in terms of agricultural potential and economic development. The analysis of thermal and hydric resources involves identifying critical parameters and thresholds at specific time intervals that correspond to the process of growth and development of the main agricultural crops during plant vegetation, from sowing up to maximum water consumption period (June to August). Through continuous monitoring and surveillance of risk/stress phenomena, the most effective measures for prevention and mitigation regarding the effects on the obtained agricultural productions can be adopted.

## CONCLUSIONS

Crop production varies year by year, being heavily influenced by fluctuations in climatic conditions and, in particular, by extreme meteorological events.

Climate variability influences all sectors of the economy, but agriculture remains the most vulnerable, and its impact is more acute at present, because climate change and variability is becoming more and more pronounced.

In Romania, the effect of climate change is felt, and these will be manifested by increasing temperatures, changing the rainfall regime, melting ice and snow, and raising sea levels.

Extreme weather phenomena leading to negative environmental impacts (floods and droughts) will become more frequent and intense in many regions. Effects on ecosystems, economic sectors, population health, and vulnerability vary from region to region.

Climate change is inevitable, which is why complementary action to adapt to its effects is needed.

The vulnerability degree of the cultivated species to the materialization of the thermal and hydric stress respectively is established on the grounds of the specific reference limits/hazard levels and classes, so as to assess the agroclimatic favourability degree of the agricultural surfaces for agricultural sorts and species with a different resilience to the occurrence of those hazards.

Thus, the analysis of the agroclimatic phenomena implying thermal and hydric stress involves identifying the critical parameters and thresholds over specific calendar intervals, corresponding to the undergoing of the growth and development processes in plants, as well as over the whole vegetation period, so that the favourability degree for agriculture from the agrometeorological standpoint is also established.

The agriculture will face more climate-related risks, the adaptation options being requiring continuing researches on the effect from irrigation and sustainability of yields under various water saving methods and irrigation technologies.

Policymakers need good information at different scales (local, regional, European, global) to identify priority issues, the most appropriate adaptation measures and economic activities.

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